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Design of Regional Monitoring of the Potential Effects of Oil and Gas Development on Groundwater Resources in California

M.K. Landon, K.A. Taylor, P.B. McMahon,
J.T. Kulongoski, M.S. Fram, & L.B. Ball,
U.S. Geological Survey

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U.S. Department of the Interior
U.S. Geological Survey

Cooperators

- California State Water Resources Control Board
  - SB4 Regional Monitoring Program - Water Quality in Areas of Oil and Gas Production
- U.S. Bureau of Land Management

- In coordination with:
  - Regional Water Quality Control Boards
  - California Division of Oil, Gas, and Geothermal Resources
  - Local water agencies

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Outline

- Project Background
- Planned components of regional monitoring
  - Salinity Mapping
  - Produced Water/End-Member Characterization
  - Regional Groundwater Risk Zone Analysis Near Oil Fields

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Project Background

- California Senate Bill 4 (2013) mandated monitoring of the effects of Well Stimulation Treatment (WST) on groundwater quality
- California State Water Resources Control Board developed monitoring criteria to be fully implemented Jan. 1, 2016
- Operators conduct local-area monitoring; USGS & State Water Board cooperating on regional monitoring

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Project Background

- In CA, the full range of effects of oil and gas development are likely to have greater effect on water quality than WST
  - Long history of oil/gas development (100+ years), enhanced recovery methods (60+ years), underground waste disposal
  - WST in CA occurs in same petroleum reservoirs developed using other methods, not new reserves (shales) (CCST, 2015)
  - CA petroleum reservoirs relatively permeable: WST wells sub-vertical, relatively smaller volumes of fluids & contaminants compared to WST elsewhere (CCST, 2015)
- These factors make it difficult to separate effects of WST from legacy oil and gas development

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Regional Monitoring Question

- Has oil and gas development as a whole contributed to changes in groundwater quality at regional scales?

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Technical Scope

- 2014-15: statewide, regional, and pilot-scale analyses providing technical support for design and planning of regional monitoring program
- 2016- regional monitoring program implementation

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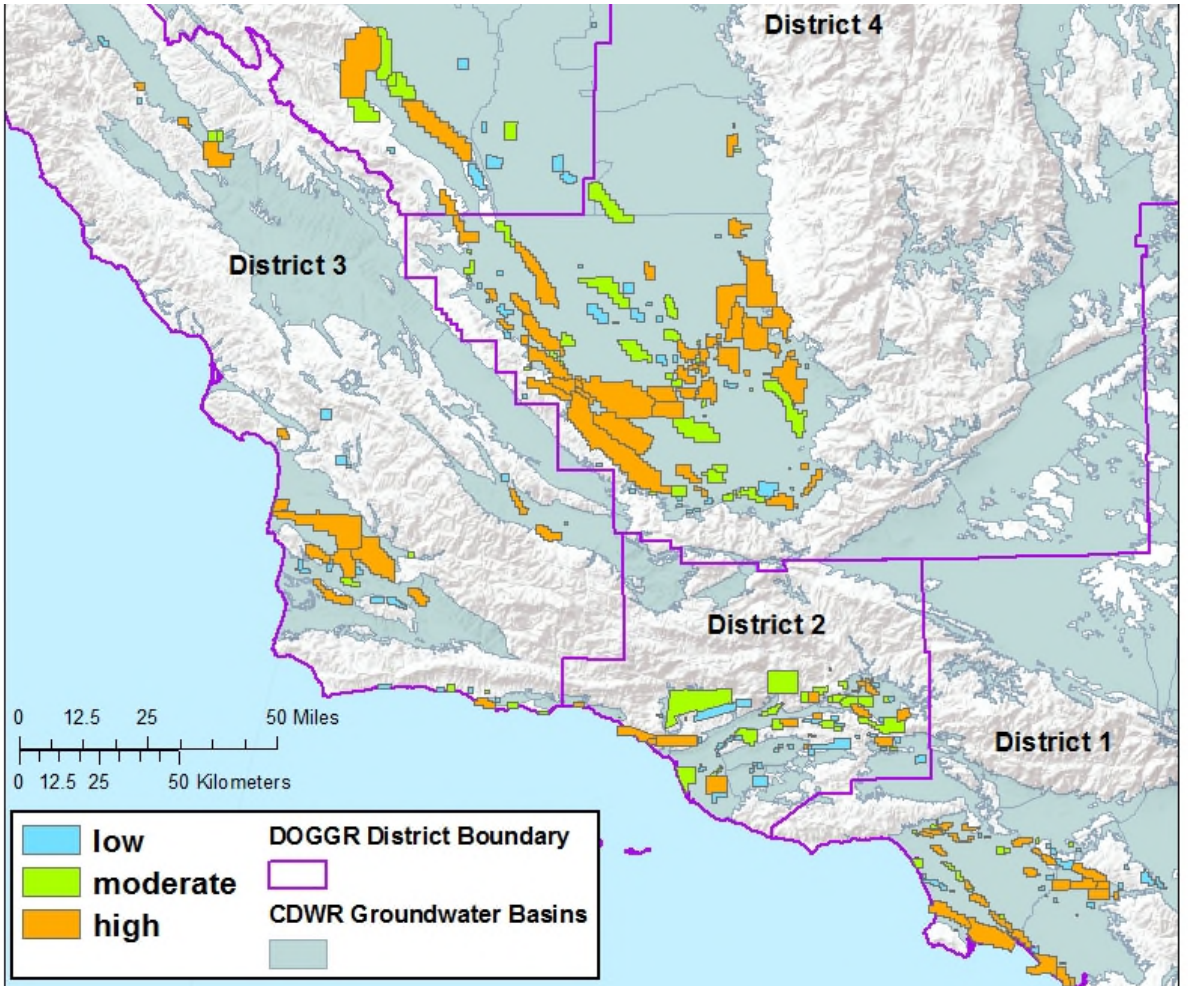
Relative Prioritization of Oil Fields for Regional Monitoring of Groundwater Based on Vertical Proximity, Well Density, & Injection Volumes



Prioritization categories for consideration in implementing regional groundwater monitoring adjacent to oil fields

Davis et al. (in review)
Subject to revision

Collaborations

- USGS
  - California Water Science Center (many)
  - Colorado Water Science Center (McMahon)
  - Crustal Geophysics and Geochemistry Center (Ball et al.)
  - Branch of Geophysics (Lane, Day-Lewis et al.)
  - National Research Program & Research Labs (Aiken, Cozzarelli, Hunt, Kharaka, Kraus, Lorah, Orem et al.)
- Cal St Univ. – Sacramento (Shimabukuro et al.)
- Cal St Univ. – Bakersfield (Gillespie)
- Oxford University (Ballentine, Barry)
- Duke University (Vengosh et al.)

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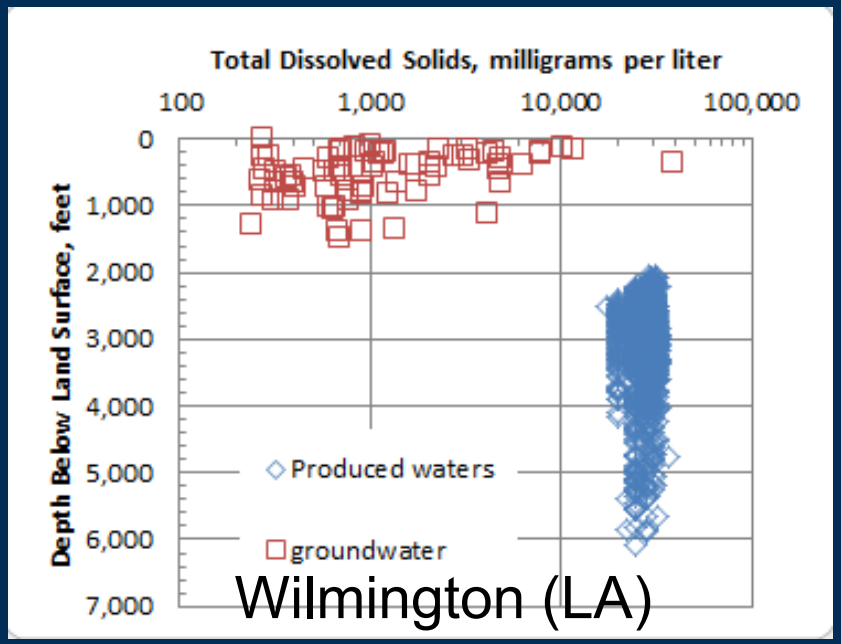
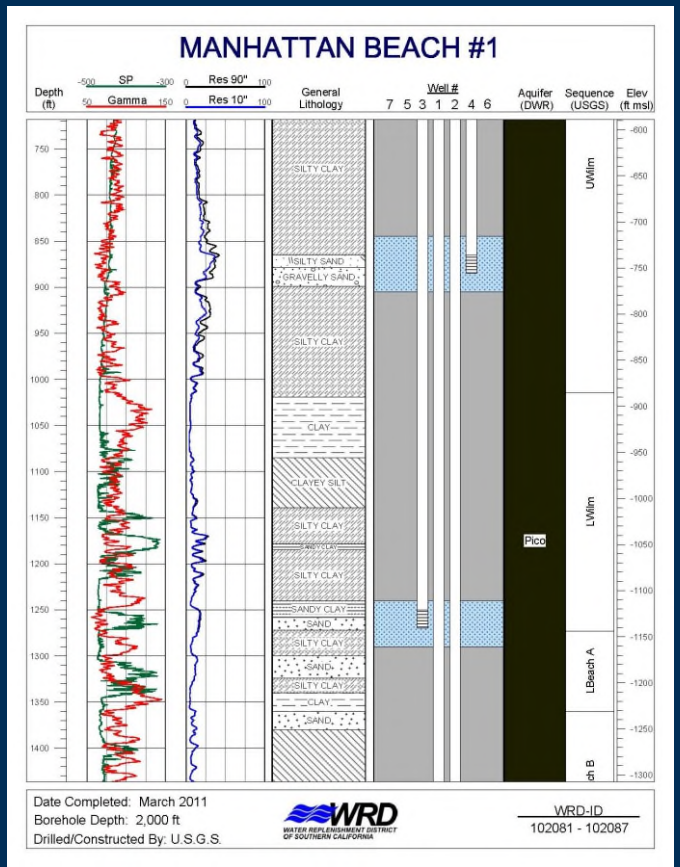
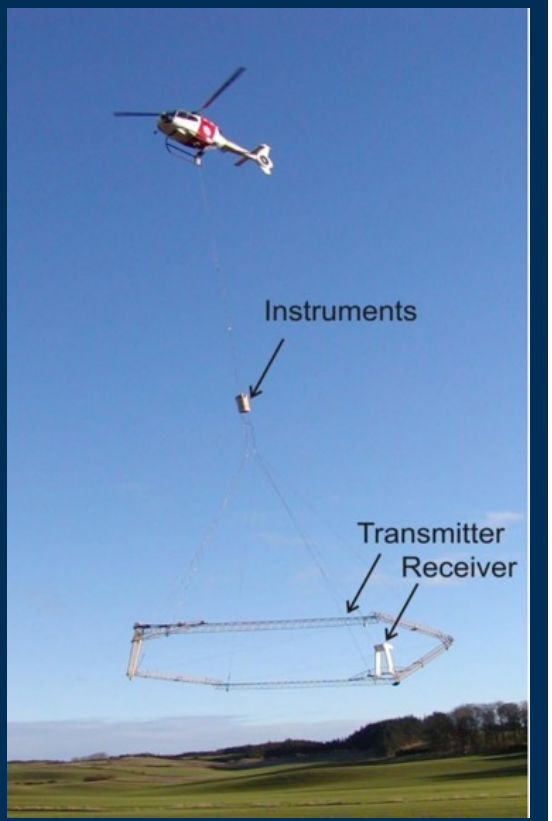
Salinity Mapping - Components

- Objective: map protected (<10K TDS) water near oil fields
- Analysis of existing water sample data
- Salinity from borehole geophysical logs
- Surface and airborne geophysics (Electromagnetic)



Wilmington (LA)





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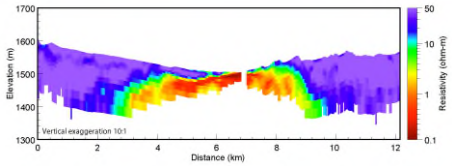
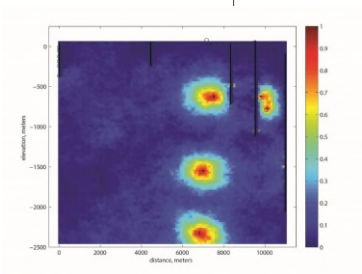
Salinity Mapping - Outcome

- Where are protected groundwater resources in relation to oil & gas development
- What lies between protected resources and oil & gas operations?

New resistivity data in buffer

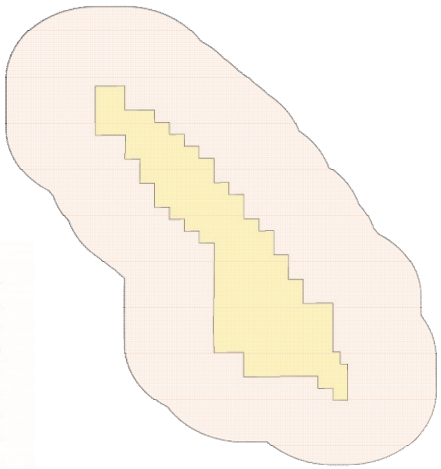


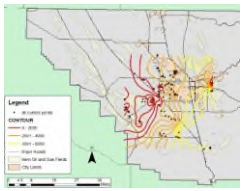


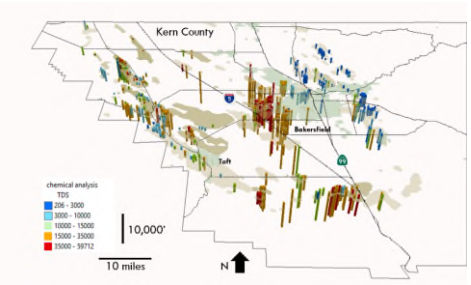
Extrapolate from sites with data using geostatistics

5 km buffer

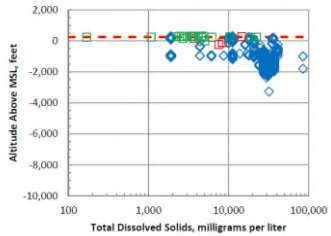
Oil field footprint



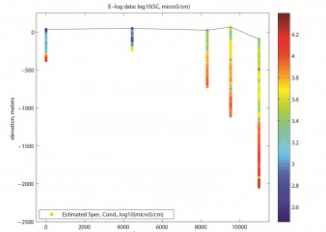




existing chemistry data—all wells

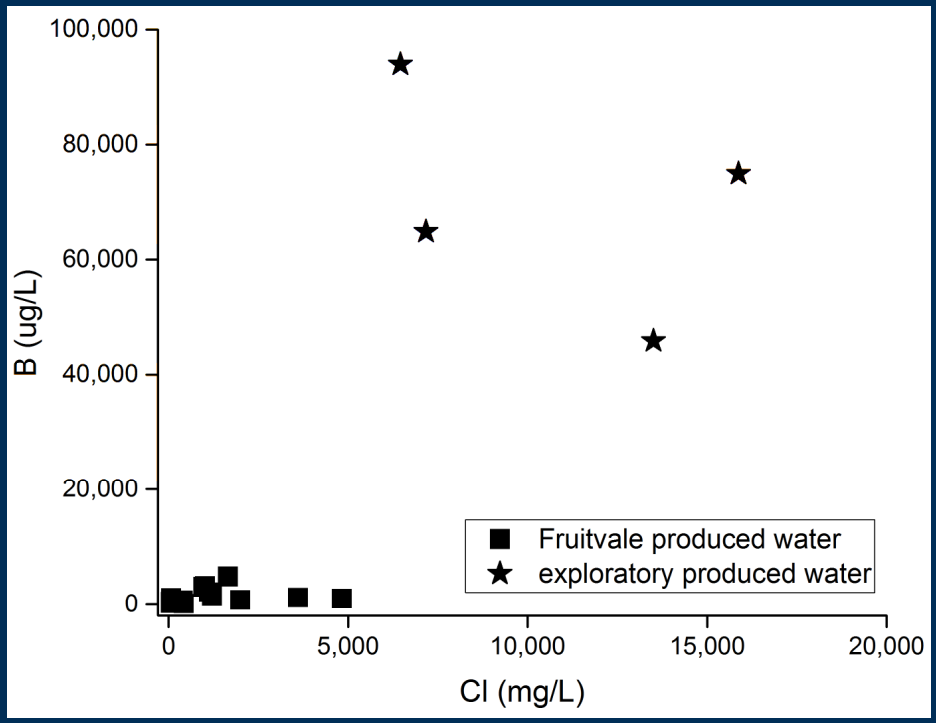


Analyze borehole logs



Produced Water Sampling

- Characterization of oil-field source waters (library)
- Oil-field water chemistry varies
- Augments other sampling efforts



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McMahon et al. (in review)

Subject to revision

Regional Groundwater Risk Zone Analysis

- Identify whether fluids from oil and gas areas may be moving into groundwater
- For priority fields or groups of fields
  - 4.1 Existing data compilation
  - 4.2 Existing data visualization/monitoring design
  - 4.3 Groundwater sampling
  - 4.4 Hydrogeologic framework analysis
  - 4.5 Drilling/well installation

Iterative cycles

- Reporting (interim and final)

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Existing Data & Geologic Framework Analysis

- Large amounts of oil/gas & water well construction, geophysical log, and lithology data being digitized so it can be used in numerical analysis (CSUS, USGS)
- Three dimensional representation of subsurface formations and/or lithology
- Provides context for understanding fluid movement & groundwater quality

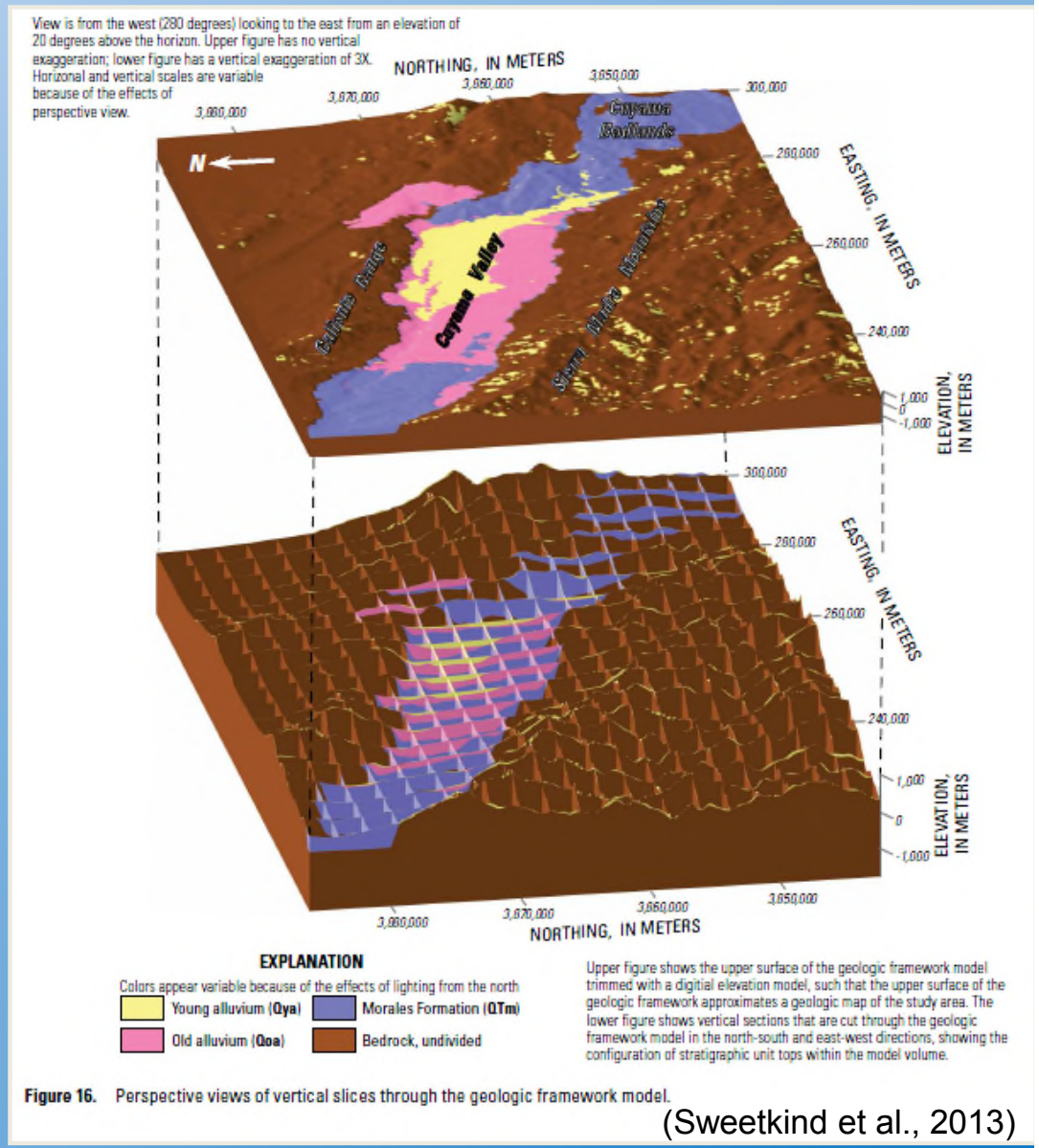
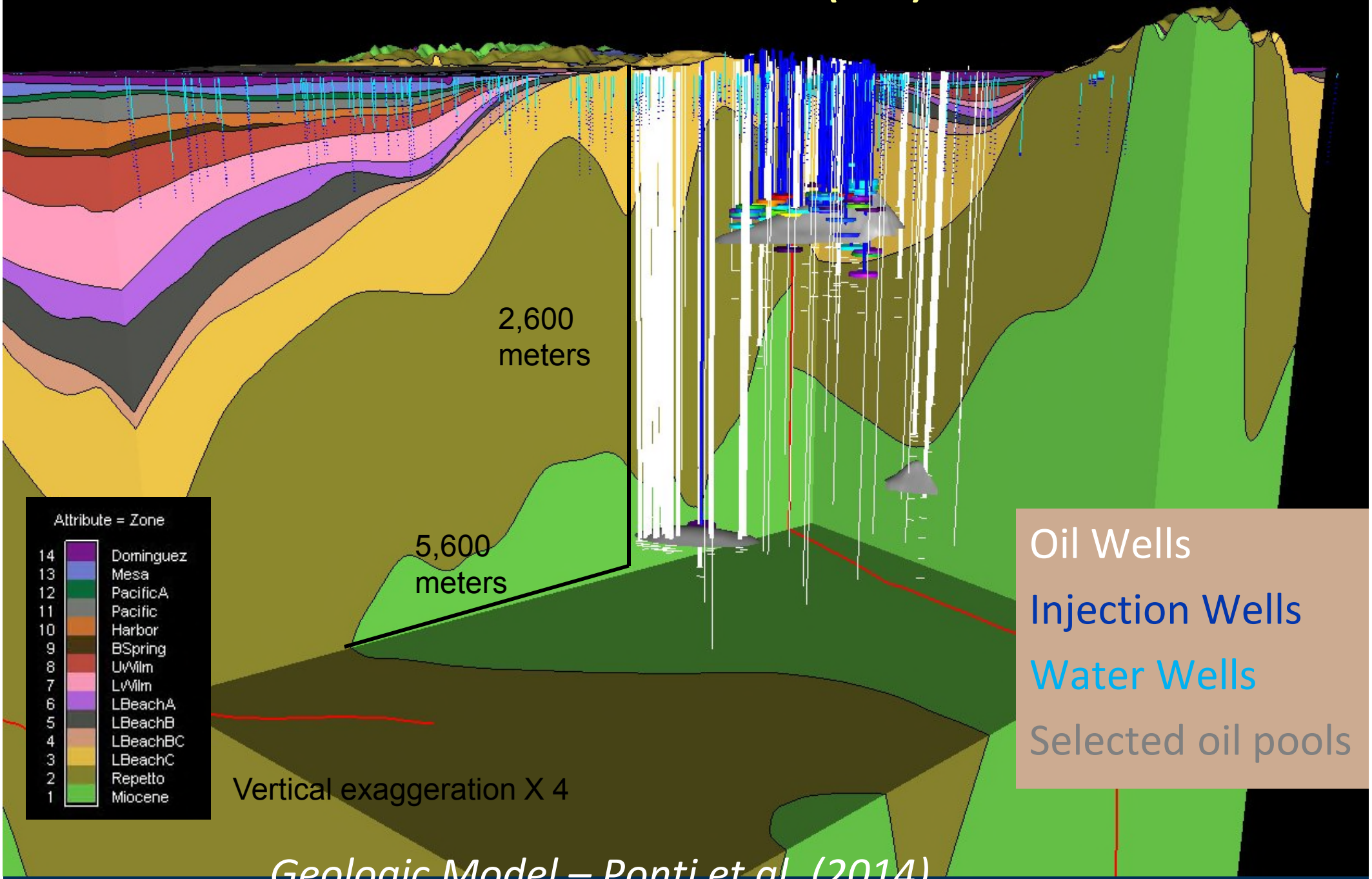


Figure 16. Perspective views of vertical slices through the geologic framework model.

(Sweetkind et al., 2013)

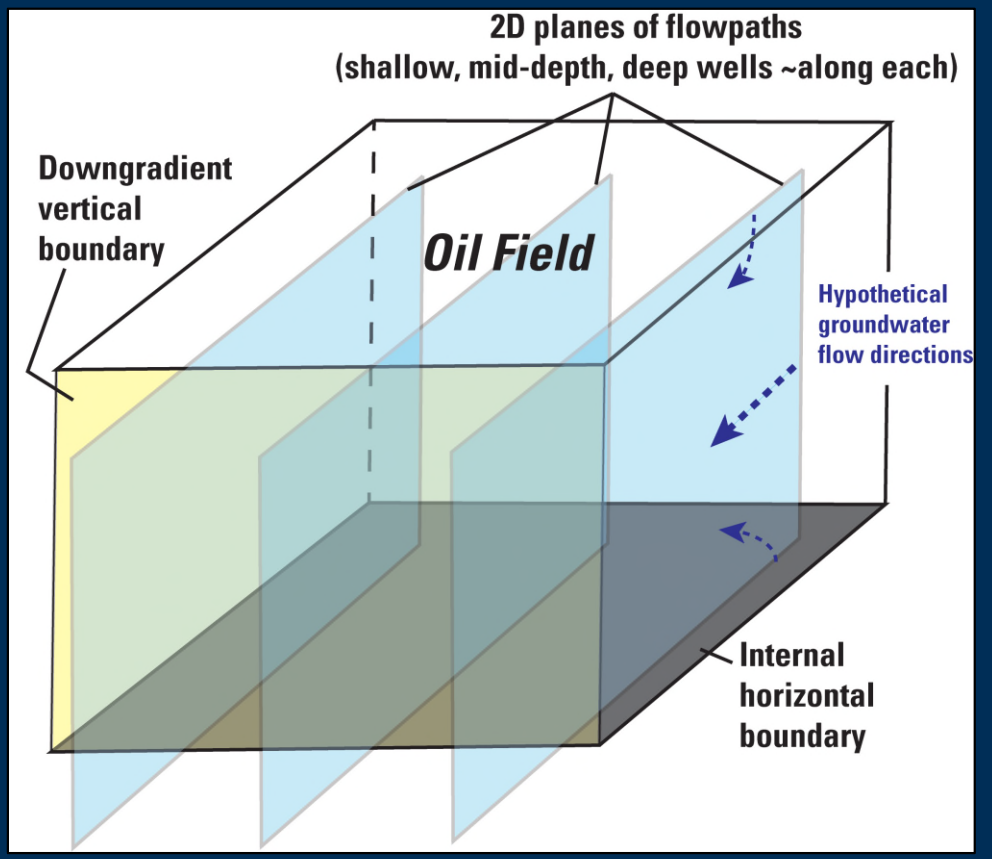
Wells Montebello Oil Field (LA)



Geologic Model – Ponti et al. (2014)

Groundwater Sampling Network Design

- Shallow, mid-depth, and deep wells along multiple flow paths in & downgradient of oil field
- Well types
  - Existing wells
  - Depth-dependent sampling in existing wells
  - Drill new monitoring wells to fill key gaps as necessary after initial sampling of existing wells



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Analytes for Produced Water & Groundwater

- C1-C6 gas concentrations and isotopes
- VOCs and semi-volatiles
- DOC, fractions, fluorescence, absorbance
- Major ions, trace elements
- Nutrients
- Ra isotopes
- δD, $\delta^{18}O$
- Sr, B, Li isotopes
- Noble and atmospheric gases
- Tritium, ^{14}C
- Low-molecular weight organic acids

Samples are being analyzed at USGS, University, and Commercial laboratories

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Kulongoski et al. (in review)

Unique to regional analyte list

Summary

- Designed to determine where and to what degree groundwater quality is potentially at risk from oil and gas production activities
- Includes salinity mapping, produced water characterization, and regional groundwater monitoring & analysis in priority areas
- Early regional monitoring (2016-17) in Kern County: begin in areas of differing hydrogeologic setting on east & west side of Central Valley

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Questions?

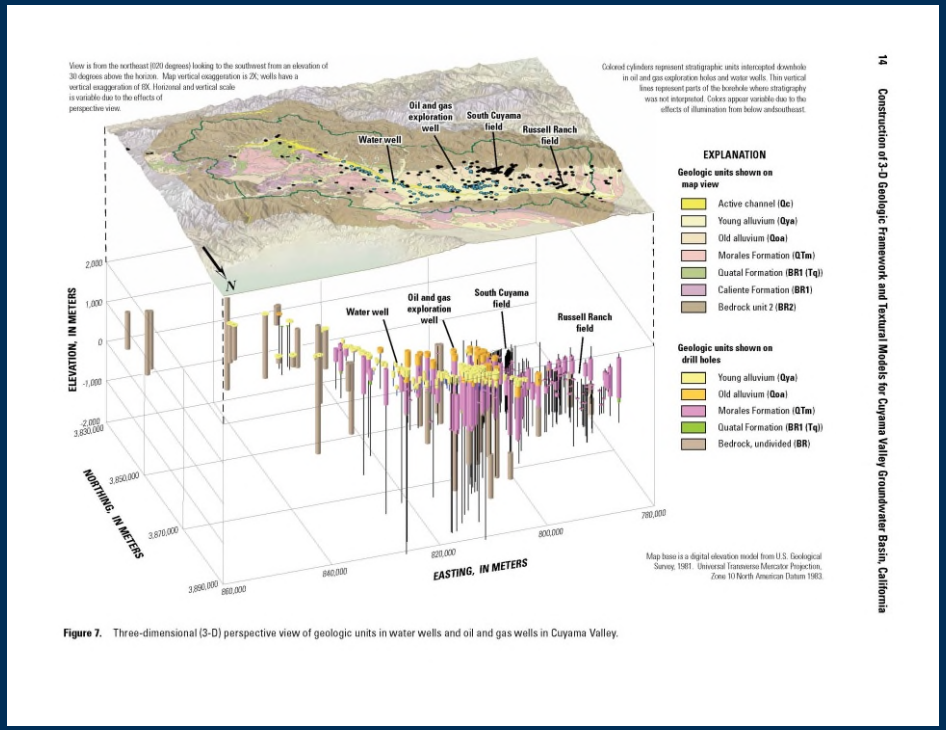

Figure 7. Three-dimensional (3-D) perspective view of geologic units in water wells and oil and gas wells in Cuyama Valley.

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California Council on Science and Technology (CCST), 2015, An independent scientific assessment of well stimulation in California, online at https://ccst.us/projects/hydraulic_fracturing_public/SB4.php

Ponti, D.J., Wagner, B.J., Land, M., and Landon, M.K., 2014, Characterization of potential transport pathways and implications for groundwater management near an anticline in the Central Basin area, Los Angeles County, California: U.S. Geological Survey Open-File Report 2014-1087, 75 p. and appendix, *http://dx.doi.org/10.3133/ofr20141087*.

Sweetkind, D.S., Faunt, C.C., and Hanson, R.T., 2013, construction of 3-D geologic framework and textural models for Cuyama Valley groundwater basin, California: U.S. Geological Survey Scientific Investigations Report 2013–5127, 46 p., http://pubs.usgs.gov/sir/2013/5127/

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